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Growth of low emission-intensive energy production and energy impacts in Vietnam under the new regulation

Duy Nong [a], Mahinda Siriwardana [b,*], Subashini Perera [b], Duong Binh Nguyen [c]

[a] Institute for Food and Resource Economics/Center for Development Research (ZEF), University of Bonn, Germany, 53115
[b] UNE Business School, University of New England, Armidale, NSW, 2350, Australia
[c] Faculty of International Economics, Foreign Trade University, Hanoi, 10000, Viet Nam

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ABSTRACT

Mitigating and adapting to the effects of climate change is an ongoing concern for developing countries like Vietnam. Hence, Vietnam ratified the Paris agreement without delay in October 2016. As a part of its climate policy strategy, the government is proposing to increase the taxes either on coal by 50% or petroleum products by 33.33%. This study employs the GTAP-E-Power model with additional improvements to include non-CO_2 emissions to examine the impacts of such a policy on the Vietnamese economy. Results show that the trade-offs of the increased tax on petroleum products (Scenario 1) are much higher than the increased tax on coal (Scenario 2). For example, real GDP in Vietnam declines by 2.23% and 1.05% in Scenario 1 and Scenario 2, respectively. In addition, the country's emissions level reduces by 10.23% in Scenario 2 compared to a reduction of 7.62% in Scenario 1. A higher tax on coal would foster the extension of renewable energy sectors faster than the impacts resulted from increasing tax on petroleum products. The increased demands by the private sector for electricity generated from renewable sources signals a potential for a sustainable development of the renewable electricity generation sectors in Vietnam.

1. Introduction

The current electricity output in Vietnam is largely generated from coal, gas, oil, and hydro power plants, while there is only a small contribution come from wind and other renewables (United States Energy Information Administration, 2015). Of these, the coal power plants have been recently targeted and developed rapidly to meet substantially increasing demands (Vietnamese Ministry of Industry and Trade, 2017). This is because the investment and operational costs of coal power plants are relatively low compared to those for other plants. In the past decades, coal power plants accounted for only a small share of electricity generation in the country, whereas hydropower is the most important source for producing electricity. This is due to natural terrain conditions in the country, as more than three quarters of Vietnam's land is mountainous with abundant water resources from 2360 rivers rapidly streaming in short distances from highland areas in the west to delta areas in the east (Fig. 1). Of these, there are 16 basins covering around 2500 km^2 with total volume of annual run-off of approximately 847 km^3 (Nguyen-Tien et al., 2018).

In 2015, fossil fuel electricity output accounted for 61% of the total electricity supply in the country, while the contribution of hydropower was 33%. Other renewable electricity generation accounted for only around 1%, and 5% of electricity supply that was imported from China and Laos (United States Energy Information Administration, 2015). Although Vietnam has a significant potential to develop electricity generation from renewables, the development of these sources is at their infancy due to technical, institutional, economic, and market barriers (Embassy of Denmark, 2017). Nguyen (2007) indicated that Vietnam would have 31,000 km^2 of land suitable for wind power development. Of these, an area of 865 km^2 constitutes potential locations to develop wind energy at relatively low costs of less than $0.06 per kilowatt-hour. However, due to aforementioned constraints, wind energy plants are emerging rather slowly in Vietnam.

The main sources of electricity generation, capacity and market shares of each type of electricity generation in Vietnam are regulated by the government. However, any condition that affects the

* Corresponding author.
E-mail addresses: duy.nong@ilr.uni-bonn.de, nongngocduy@gmail.com (D. Nong), asiriwar@une.edu.au (M. Siriwardana), mahangam@une.edu.au (S. Perera), duongnb@ftu.edu.vn (D.B. Nguyen).

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Abbreviation

BL	Base load
CES	Constant elasticity of substitution
c.i.f price	Cost insurance and freight price
CO_2	Carbon dioxide
CGE	Computable general equilibrium
ETS	Emissions trading scheme
EU 28	28 country members of the European Union
f.o.b	Free on board price
GDP	Gross domestic product
GTAP-E-Power	The Global Trade Analysis Project Energy/ Environmental Power model
PL	Peak load
S1	Scenario 1
S2	Scenario 2

fossil fuel prices would also affect the development and market shares of electricity sources. This is because primary energy sources, such as coal, oil, gas, and petroleum products are the main inputs to the thermal electricity generation sectors that produce electricity. Such price changes of fossil fuels also affect the development of renewable electricity generation sectors due to substitution effects for fossil fuel electricity generation outputs.

In this context, fuel policies may considerably affect the growth and market shares of each electricity source in Vietnam. In particular, the Vietnamese Government has proposed to increase the tax rates on consumption of coal and petroleum products by 50% and 33.33%, respectively (Das, 2018). The primary purpose of the tax proposal is to encourage consumption and production of cleaner energy, as well as to reduce the emissions levels because Vietnam has committed to reduce its emissions levels at the Paris Climate Change Conference. Such tax increases on two main sources of energy may substantially affect the country because they are the main inputs for many sectors. In addition, coal and petroleum products are used extensively for electricity generation. Increased taxes on these commodities would lead to contractions of those electricity generation sectors, while fostering the development of cleaner electricity generation sectors, such as gas-fired electricity, hydroelectricity and other forms of renewable electricity.

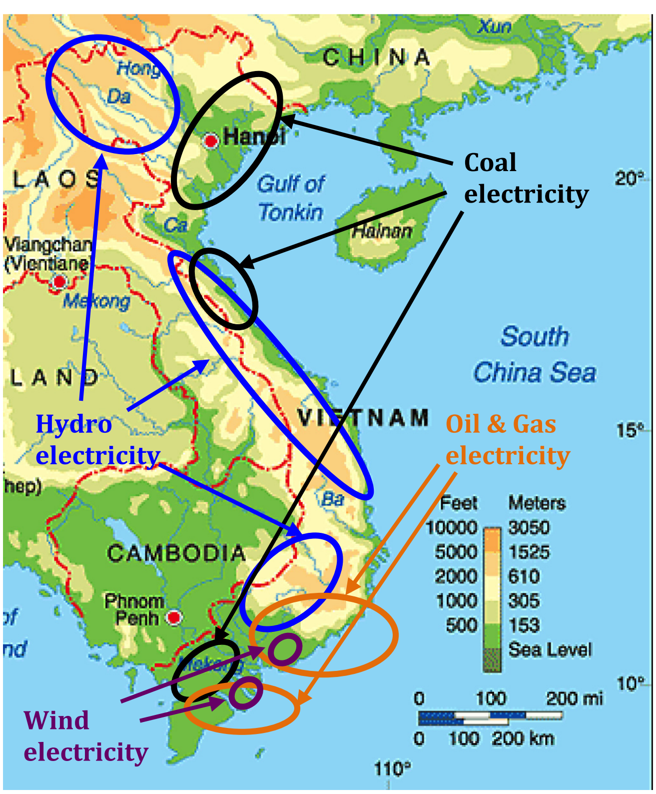


Fig. 1. Vietnam's physical map and areas for electricity generation.
Source: The Vietnamese Ministry of Industry and Trade (2017).

This study aims to examine the effects of the increased tax rates on coal and petroleum products on the Vietnamese economy, particularly focusing on the electricity generation and other energy sectors. The study will make a substantial contribution to the literature because such studies are yet to emerge in Vietnam and in many other developing economies. First, the study addresses a wider audience to give a better understanding of energy sectors and electricity production in Vietnam. The country is a rapidly growing economy in the Southeast Asian region with abundant energy resources for producing electricity and exporting it to other nations nearby; however, available information about the country's energy sources, energy trading, as well as electricity generation potential is still limited.

Second, this study will significantly fill the gap in the literature concerning environmental policy developments in Vietnam. To date, only two studies have examined the impacts of an environmental tax in the country. The first study was conducted in 2002 when the policy was first proposed, while the second study was published in 2013 when the policy was implemented. Since then, no study has been conducted to analyze the likely impacts of the environmental policy in Vietnam even though the two existing studies have focused on limited issues.

Third, this study is also expected to make a significant contribution to electricity market and modeling. The Global Trade Analysis Project Energy/Environment Power (GTAP-E-Power) model is employed for this investigation. This model is an electricity-detailed economy-wide computable general equilibrium (CGE) model. There are several CGE models in the literature that show the nested production structure for electricity generation based on different technologies. Each of these models has both advantages and disadvantages compared to others (Peters, 2016a). However, the GTAP-E-Power model has two major distinct advantages; substitution parameters are estimated according to a sound econometric study, and electricity generation and demands are divided into base load and peak load technologies. This model is particularly suitable for studying electricity sectors and markets in Vietnam because demands for electricity are widely different during the day and between seasons (Gerner et al., 2017). Hence, the impacts of government tax policy on electricity sectors and markets can be accurately estimated using this approach. In addition, we develop this model further to include additional emission variables that account for non-carbon dioxide (non-CO_2) emissions so that the model can capture almost entire emission levels in each economy. A new two-stage CGE modeling simulation is also used to examine the impacts of the increased taxes. It helps to understand the direct impacts of the policy in the second stage while accounting for electricity production growth in the first stage. In particular, at stage 1, we based on the government's goal to project the growth rate of electricity output capacity for each electricity generation sector. This provides the baseline for stage 2 of which the increased taxes on either coal or petroleum products are implemented.

The remaining sections of this paper are organized as follows: Section 2 provides the literature review on energy or fuel taxes

generally and on energy studies in Vietnam. This section intends to provide an overview of studies related to energy policies in several countries, as well as in Vietnam in order to find out their limitations or restrictions so that it eventually strengthen the methods and findings of this study. Section 3 specifies the model, data, and scenario design to help readers understand how we yield the results. Section 4 reports the modeling results and discussion; while Section 5 provides the concluding remarks and policy implications.

2. Literature review

Climate change is widely recognized as a significant and growing threat for the future well-being of humanity and for the living environment of all live entities. To reduce the extent of this threat, many countries around the world have considered and/or implemented the climate change policies to reduce the greenhouse gas emissions into the atmosphere. For example, the European Union, South Korea, New Zealand, and other regions have implemented the emissions trading schemes to curb the greenhouse gas emissions (Simshauser and Tiernan, 2018; Siriwardana and Nong, 2018). Australia introduced the Carbon Price Mechanism in 2012 but later replaced it with a Direct Action Plan in 2014 (Meng et al., 2018). China has also introduced the carbon tax to curb the emission levels (Li and Masui, 2018). The literature on this topic therefore grows quickly with rapidly increasing number of research articles.

The computable general equilibrium modeling approach has been widely used to assess the impacts of climate change, energy, and fuel taxes on various economies. Of these, there is a substantial number of studies focusing on large economies or polluters, such as China, United States, the European Union, India, and Australia (Babatunde et al., 2017). The studies particularly focusing on energy and/or electricity sectors, for example, include Orlov (2015), Nong et al. (2017), Meng et al. (2018), Nong and Siriwardana (2018b), and Bachner et al. (2018). Meng et al. (2018) integrated a national CGE model with the sub-electricity model to examine the impacts of an ETS on various electricity and other energy sectors in Australia. Nong and Siriwardana (2018a) investigated the impacts on the United States economy and energy sectors in a scenario where the country withdrew from the Paris Agreement. Studies on fuel taxes have also been growing quickly because such a taxing mechanism is considered an effective instrument to reduce the consumption of fuels, as well as to reduce the emissions levels. For instance, Zhao et al. (2018) estimated the impacts of gasoline consumption tax on the consumption and carbon emission levels in China. Zhao et al. (2018) found that demand for gasoline in China is not highly elastic, but the tax can help the country to reduce its emissions substantially. Feng et al. (2018) found that energy subsidies would be a very expensive policy instrument to transfer income to low-income groups in South America. Feng et al. (2018) uncovered that high-income groups would experience more benefits than low-income groups when the prices of energy are low. Some other similar studies include Adom et al. (2017), Awad et al. (2017), Zhang et al. (2017), and Nong (2018).

In Vietnam, the environmental tax has been considered for two decades and an effective environmental tax was introduced in 2012.[1] However, there are only a few studies that assess the efficiency and impacts of such a policy on the Vietnamese economy and specific sectors. By contrast, some studies focus on smaller segments of the economy and energy sectors. For example, Le et al. (2013) estimated the social costs of fossil fuels and biofuels in Vietnam. Zimmer et al. (2015) investigated the motivations for Vietnam for introducing climate change policies to help the country move towards a low carbon economy. Ha-Duong and Nguyen-Trinh (2017) examined the likely impacts of different carbon capture and storage techniques.

The studies that are able to assess the impacts of the environmental tax on the Vietnamese economy are extremely scant, with only two studies in 2002 and 2013. El Obeid et al. (2002) employed a CGE model to assess the impacts of the proposed environment tax in Vietnam, but the study provided little information of the effects on the Vietnamese economy, as well as on the electricity generation sectors. When the environment tax was first introduced in 2012, Coxhead et al. (2013) used a national static CGE model for Vietnam to estimate the impacts of such a tax on the Vietnamese economy and different household groups. Coxhead et al. (2013) linked national household survey data with input-output data in their investigation. The specific tax rates to the units of fuel used were also converted to ad valorem taxes. Under different assumptions of labor supply, the simulation results show that Vietnam experiences only a slight decrease in its real GDP within the range 0.35%–0.63%. Crude oil and petroleum products reduce their output levels considerably, while other fuel sectors experience relatively low reductions in their output levels. In addition, urban households are projected to experience higher negative impacts relative to rural households. These studies, however, present simple production and demand structures related to energy in their models. The data employed were also well before the year of study, but databases were not updated. In addition, only CO_2 emissions are considered in their studies. These studies also did not consider growth of key energy sectors in the study period, which may have distorted the results. This is because such growth if included would change the structure and market shares in an economy so that the final results based on such an updated database would differ considerably when a target policy is introduced.

The Vietnamese Government has recently proposed to increase these fuel taxes, which would have significant implications for the Vietnamese economy, as well as the electricity generation and other energy sectors. How these increased taxes would affect the economy, and the thermal electricity and renewable electricity generation sectors are still unclear. Given it is a topical issue and studies in Vietnam are limited, there is a need for a study that is able to project the impact of such a policy on the country and overcome limitations of previous studies. In the event that the tax rates are sharply increased, they may considerably affect the country's economy, energy security and the development of electricity generation sectors, as well as households' income and consumption levels. The present study takes these crucial impacts into consideration to make a significant contribution to the literature on this topic that would aid the future environmental policy developments in Vietnam.

3. The GTAP-E-Power model and electricity production in Vietnam

3.1. The model of specific electricity generation in Vietnam

This study uses the GTAP-E-Power model (Peters, 2016a) with an extension to include additional non-CO_2 emissions to examine the impacts of the increased tax rates on coal and petroleum products on the Vietnamese economy and various electricity generation sectors. GTAP-E-Power is an extended version of the GTAP-E model (McDougall and Golub, 2007), which has been used widely for policy and energy economics assessments (for example, see Beckman et al. (2011); Oladosu (2012); Cai and Arora (2015); Nong et al. (2018)). The computable general equilibrium (CGE) approach

[1] See http://www.greenfiscalpolicy.org/wp-content/uploads/2013/08/Environmental-Taxation-in-Vietnam.pdf.

is the most appropriate methodology to examine the economy-wide impacts of a policy (e.g., an energy tax) (Dixon and Jorgenson, 2013). Partial equilibrium analysis is also one method but such a tool only focuses on a small segment of an economy, such as particular sectors. In that case, the relationship and interaction between all sectors are missed. However, the CGE modeling approach includes various models. Of these, the GTAP-E-Power model has numerous advantages. First, it has details of electricity generation sectors using different technology, including several renewable energy sectors. Second, only few CGE models, including the GTAP-E-Power model, separate electricity generation and demand into base load and peak load due to different levels of demands for electricity during the days, seasons, and weeks (Peters, 2016a). As a result, this model could be considered as one of the most powerful CGE models to study energy related issues. Third, almost all CGE models and data are not publicly available, while the GTAP-E-Power model and its data are available at an affordable fee. This allows us to process and modify the model according to our needs.

In general, GTAP-E-Power retains the entire theoretical framework of GTAP-E, except the structures of electricity production and consumption. Fig. 2 outlines the production structure in the GTAP-E-Power model. It is noted that GTAP-E-Power is a multi-country and multi-sectoral CGE model; hence, the production structure presented in Fig. 2 is a representation for each industry in each country. There are 11 electricity generation sectors in the GTAP-E-Power model based on two different technologies (i.e., base load and peak load) and energy sources. The division of the electricity generation sector into various sub-sectors is based on the fact that electricity is not able to be stored. That is, the supply of electricity must instantaneously meets demand for electricity but demand may fluctuate considerably in different times of the day, week, and season. Some generation technologies such as coal-fired technology, however, cannot adjust output quickly to follow a suddenly increasing demand. Hence, it is practical to divide the generation technology into base load and peak load technologies in order to provide a unique market for each type of generation technology. This structure of the model is particularly suitable to study an energy policy in Vietnam because demands for electricity in the country have changed rapidly during the time of days, weeks, and seasons. For the base load technology, there are seven sources of electricity generation, such as nuclear, coal, gas, oil, hydro, wind, and other renewables. In Vietnam, nuclear electricity generation is still under consideration (Electricity of Vietnam, 2018), while oil-fired technology is not used as a base load technology. There are four types of the peak load technology in the model; they are gas, oil, hydro, and solar. Of these, only gas and oil peak load technology are in operation in Vietnam; hydropower is only used as a base load technology, while solar energy produces only a relatively small fraction of electricity and is considered as a base load technology, which is grouped with other renewables (Peters, 2016b).

As shown in Fig. 2, each sector selects intermediate inputs, labor and capital based on various levels of the Leontief and constant elasticity of substitution (CES) functions in order to minimize their costs. The Leontief function at the top level allows the industries to select the endowment-energy composites and non-energy inputs in fixed proportions to outputs without substitution possibilities. On the other hand, the CES functions allow the industries to select inputs in each group based on price changes of inputs. For example, in order to form a non-coal composite, a sector can increase demand for gas to substitute for oil and petroleum products when gas becomes relatively cheap compared to oil and petroleum products. Each sector also has particular demand for electricity. A base load composite and peak load composite are selected within their groups via the CES functions. However, the peak load and base load composites are not substitutable for each other. In addition, transmission services are used in parallel with electricity inputs.

We develop the model further by incorporating non-CO_2 emission variables, as the GTAP-E-Power model only includes CO_2 emission variables, which are tied to demands for energy commodities by industrial, private, and public sectors. In this instance, non-CO_2 emissions released from energy consumption are incorporated by linking with demands for energy commodities by industrial and private sectors. In addition, non-CO_2 emissions released from production processes are tied with output level of industries. The non-CO_2 emission variables, which show the

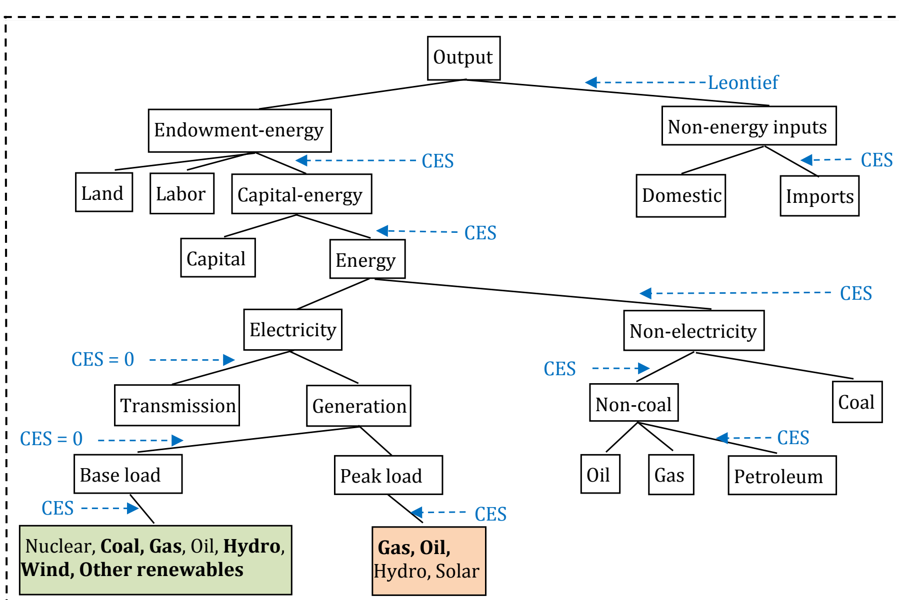


Fig. 2. The production structure in the GTAP-E-Power model.
Note: Words in bold in the green and orange boxes indicate the electricity technologies in Vietnam. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 1
Growth rates of key variables in 2011–2018 (percentage change).

	Investment	Unskilled labor	Skilled labor	Capital	Population	GDP
Vietnam	52.68	9.88	9.88	70.34	7.97	42.24
Japan	11.75	−3.79	−3.79	31.19	−1.84	8.26
USA	17.03	5.30	5.30	41.14	6.32	13.94
China	98.23	1.84	1.84	185.14	3.96	52.18
EU28	16.65	−0.54	−0.54	52.23	1.07	8.47
ROW	36.65	9.18	9.18	76.10	7.01	23.04

Source: Diffenbaugh et al. (2012) and the International Monetary Fund (2018).

emissions levels from using endowment factors, are also included in the model. These variables vary depending on the fluctuations of demands for endowment factors. In other words, non-CO_2 stationary and fugitive emissions will change at the same rate with demands for and supplies of commodities, respectively.

3.2. Database and scenario design

The GTAP-Power database (Peters, 2016b) version 9 is used for the GTAP-E-Power model. This database includes detailed information related to the electricity generation and transmission sectors. The database has 140 regions and 68 sectors with the base year of 2011. For this study, this database is aggregated into 6 regions and 33 industrial sectors (see Table A1 in Appendix A). We also incorporate non-CO_2 emissions data compiled by the GTAP group (Irfanoglu and van der Mensbrugghe, 2015) to the database to make it compatible with the extended version of the model. A summary of the database and a map of country regions are provided in Tables A2 and A3 and Figure A1 in Appendix A.

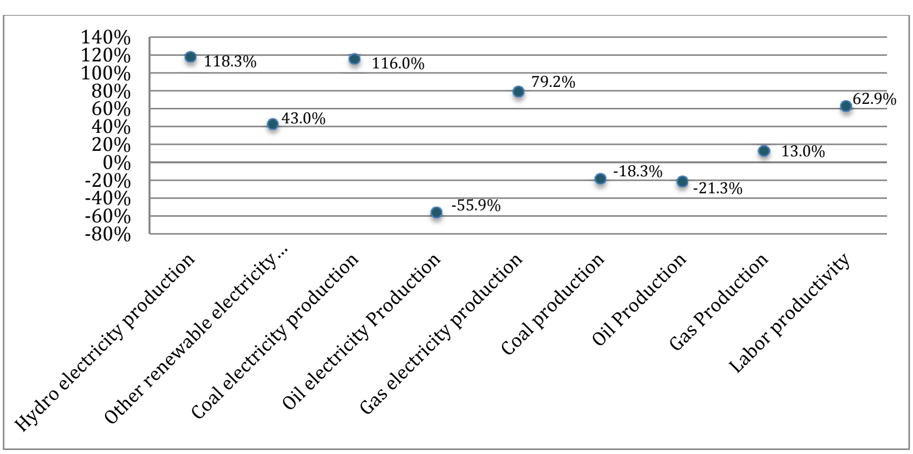
The database is updated from 2011 to 2018 by using macroeconomic projections provided in Table 1 and Fig. 3. In particular, the projections of real GDP are provided by the International Monetary Fund (2018), while projections of investment, labor supply, capital stocks, and population are collected from Diffenbaugh et al. (2012). Particular output growth of energy sectors and labor productivity for all industries in Vietnam in 2011–2018 are collected from the CEIC (2018) as shown in Fig. 3.

The two-stage CGE modeling approach was used, following Nong and Siriwardana (2018b) for assessing the impact of increased tax rates on the Vietnamese economy and the electricity generation sectors. Such a two-stage approach is used to estimate the direct effects of the increased tax rates, while it also accounts for targeted/projected output growth of electricity anticipated by the government. That is, in Stage 1 the growth in electricity generation is projected based on the government's target. A long-run closure was adopted for the model simulations. In particular, the real wage rate and capital stock remain flexible, whereas the employment level and rate of return on capital are fixed (Adams, 2005).

At this stage, the output capacity for each electricity source in Vietnam in the long run is projected as shown in Table 2 (Vietnamese Ministry of Industry and Trade, 2017). The length of the short run or long run estimates is somewhat arbitrary; it is therefore presumed that a long run would imply about seven years in this study. The electricity output capacity growth rates reported in Table 2 are calculated from the output capacity in 2017 and targeted output capacity in 2025 provided by the Vietnamese Ministry of Industry and Trade (2017). The growth rates in the electricity output capacity for each electricity generation sector are assumed to be fully absorbed by the output augmenting technical change variables in the model. We subsequently shock this variable for Vietnam with corresponding values shown in Table 2 in order to obtain the equilibrium status for Vietnam in Stage 1.

Stage 2 represents the Vietnamese economy moving from the equilibrium in Stage 1 by introducing the increased tax rates on coal and petroleum products. Two scenarios were examined at Stage 2 and the results are reported for the long run case starting from 2018 by taking the differences in the economy between the equilibriums in Stage 2 and the equilibriums in Stage 1. The two scenarios are described as follows.

- S1 (petrol tax): a 33.33% tax increase on petroleum products.
- S2 (coal tax): a 50% tax increase on coal.



Source: The CEIC (2018).

Fig. 3. Particular sectoral projections for Vietnam in 2011–2018 (percentage change).

Table 2
Output capacity growth for each electricity generation sector in Vietnam in the short run.

Electricity sector	Output capacity in 2017 (Megawatt) (2)	Targeted output capacity in 2025 (Megawatt) (3)	Output capacity growth (% change) (4)
Hydro	18,004	22,201	23%
Coal	14,595	47,600	226%
Oil	1242	2144	73%
Gas	7446	12,856	73%
Wind and other renewables	135	7824	5696%

Note: The information in columns (2) and (3) is provided by the government, while the growth rates in column (4) are calculated from the information in columns (2) and (3).
Source: The Vietnamese Ministry of Industry and Trade (2017).

Since the GTAP-E-Power model applies a linear modeling approach, the results that show the impacts on the Vietnamese economy when these two policies are implemented concurrently are predictable. That is, such results are the aggregated level of the results shown in Scenario 1 and Scenario 2.

4. Results and discussion

This section provides the overall impacts of the increased energy taxes on energy sectors and the Vietnamese economy. An additional analysis of the robustness of results via a sensitivity analysis is provided in Appendix B.

4.1. Impact on electricity and other energy sectors

Table 3 provides the percentage and absolute changes in output levels of energy sectors in Vietnam. It is evident that the impacts on the Vietnamese energy sectors are substantially different between the two scenarios of increased taxes on petroleum products and coal.

When the tax on petroleum products (Scenario 1) increases by 33.33%, the output level of the petroleum products manufacturing sector declines by 22.78% (or $1853.9 million). Such a high reduction rate in the output level is due to the contraction of demand by other sectors for petroleum products to avoid increased costs. The coal and oil extraction sectors are also affected because these sectors also use petroleum products as inputs in their production processes. As a result, the increased tax on petroleum products increases input costs for these users. Hence, the output levels of the coal and oil extraction sectors will decline by 5.9% (or $256.3 million) and 2.51% (or $238.4 million), respectively. The gas extraction sector will only slightly reduce its production level by 0.38% (or $43.3 million). The effects on the output levels of these sectors are different because of different consumption levels of petroleum products by these sectors. In addition, other sectors also substitute coal, oil, and gas for petroleum products at different rates; hence, the effects on these sectors differ.

In Scenario 1, the higher tax on petroleum products also increases the production cost of the gas-fired base load electricity generation sector because petroleum products are inputs to this sector; the other base load electricity generation sectors do not use petroleum products. As a result, the gas-fired base load electricity generation sector reduces its output level by 11.98% (or $259.3 million). Other base load electricity generation sectors increase their output levels to compensate shortfalls in the output level of the gas-fired base load electricity generation sector. Of these, the coal, wind, hydro and other renewable base load electricity generation sectors experience increased output levels by 0.7% (or $14.4 million), 0.46% (or $0.01 million), 0.11% (or $4.7 million), and 1.42% (or $ 0.01 million), respectively. Both gas-fired and oil-fired peak load electricity generation sectors also suffer increased costs of using petroleum products due to increased taxes, leading to reductions in their output levels. However, the former uses a relatively small amount of petroleum products compared to the consumption level of the latter; hence, the former only reduces its output level by 1.92% (or $39.4 million), while the latter lowers its output level by 5.7% (or $152.3 million). Since the losses considerably outweigh the gain in electricity generation, the electricity transmission sector experiences a decline in its output level by 3.19% (or $437.03 million).

The effects on these energy sectors are considerably different in Scenario 2 when the tax on coal is increased by 50%. With a substantially increased tax on coal, all sectors reduce demand for coal, leading to a reduction in the output level of the coal extraction sector by 41.22% (or $1790.7 million). These sectors also tend to substitute other energy inputs for coal to avoid increased costs of using coal, leading to increased demands for oil, gas, petroleum products, and electricity. As a result, the output levels of the oil

Table 3
Changes in output of energy sectors in Vietnam.

Sector	S1 (petrol tax)	S2 (coal tax)	S1 (petrol tax)	S2 (coal tax)
	(% change)	(% change)	(Absolute change) ($ million)	(Absolute change) ($ million)
Coal mining	−5.9	−41.22	−256.3	−1790.7
Oil extraction	−2.51	0.83	−238.4	78.8
Gas extraction	−0.38	3.09	−43.3	351.9
Petroleum products	−22.78	0.1	−1853.9	8.1
Electricity transmission	−3.19	0.74	−437	101.4
Base load electricity				
Coal electricity	0.7	−14.64	14.4	−301.2
Gas electricity	−11.98	7.71	−259.3	166.9
Wind electricity	0.46	7.71	0.01	0.19
Hydroelectricity	0.11	7.72	4.7	327.8
Other renewable electricity	1.42	7.70	0.01	0.08
Peak load electricity				
Gas electricity	−1.92	−2.23	−39.4	−45.7
Oil electricity	−5.7	−2.21	−152.4	−59.1

extraction sector increase by 0.83% (or $78.8 million), gas extraction sector by 3.09% (or $351.9 million), petroleum products manufacturing sector by 0.1% (or $8.4 million), and electricity transmission sector by 0.74% (or $101.4 million). In Scenario 2, when costs of coal increase, the production cost of the coal-fired base load electricity generation sector will increase. Consequently, this sector will significantly reduce its output level by 14.64% (or $301.2 million). Costs of electricity output from this source will also increase compared to those from other base load electricity technologies because the other electricity generation sectors do not use coal in their production processes. Consequently, sectors will increase demands for electricity from other generators to substitute for electricity generated from coal-fired base load technology. This will lead to increased electricity outputs of gas-fired, wind, hydro, and other renewable base load electricity generation sectors by around 7.7%. Of these, the hydro and gas-fired base load electricity generation sectors experience the highest increases in their output levels in terms of absolute values by $327.8 million and $166.9 million, respectively. The impacts on the gas-fired and oil-fired peak load electricity generation may need more explanation. These two sectors do not use coal as inputs; however, they use coal-fired base load electricity as inputs in their production processes. Hence, these two sectors also face increased costs due to increased supply price of coal-fired base load electricity. Consequently, the gas-fired and oil-fired peak load electricity generation sectors reduce their output levels by 2.23% (or $45.7 million) and 2.21% (or $59.1 million), respectively.

Table 4 provides the electricity prices associated with different technologies and sources (columns 2 and 3), and private demands for electricity in Vietnam (columns 4 and 5). In Scenario 1, when the tax on petroleum products increases by 33.33%, the electricity price generated from gas-fired base load technology considerably increases by 11.28% compared to price increases from other base load technology sources. Such an increase of electricity price is the result of reduced electricity supply generated from gas-fired base load technology (see Table 3). The private demand for electricity generated from gas-fired base load technology declines by 3.25% in response to the price hike (column 4 in Table 4). While the private sector reduces its demand for electricity generated from gas-fired base load technology, it increases demands for electricity generated from other base load technologies such as coal-fired (11.22%), wind (12.21%), hydro (9.74%), and other renewables (11.93%).

The effects on prices of electricity generated from different sources may need more explanation. The price is determined by adjustments of the supply and demand curves, as well as the slopes of these curves. In Table 3, Scenario 1 shows that the output levels of the coal-fired, wind, hydro, and other renewable electricity generation sectors slightly increase; such increased electricity supply would reduce the prices of electricity generated from these sources. However, demands for electricity generated from these sources will also increase due to substitution away from electricity generated from gas-fired base load technology. The supply and demand are adjusted until the new equilibrium prices are determined. The changes in equilibrium prices may be negative or positive, depending on the effects on the supply and demand curves, and the elasticity of these curves. In this instance, the prices of electricity from each base load source will increase, for example from coal-fired (0.93%), wind (1.3%), hydro (1.68%), and other renewable (0.79%). Such increases indicate that either the impacts on the demand side outweigh the impacts on the supply side or the demand curves are more elastic than the supply curves. However, the absolute values of the impacts on the prices of electricity generated from these base load sources are relatively smaller than the impact on the price of electricity generated from gas-fired base load technology. This is because electricity generated from these sources are substitutes for electricity generated from gas-fired base load technology.

Similarly, the prices of electricity generated from oil-fired and gas-fired peak load electricity respectively increase at different rates of 20.82% and 11.74% in Scenario 1 because both sectors suffer increased production costs. However, the effect on the supply of the oil-fired peak load electricity generation sector is higher. As a result, the impact on the price of electricity generated from gas-fired peak load technology is relatively smaller than the impact on the price of electricity generated from oil-fired peak load technology. Such effects on the prices of these electricity commodities eventually reduce private demands for peak load electricity generally.

In Scenario 2, when the tax on coal increases by 50%, the price of electricity generated from coal-fired base load technology increases by 21.49%, leading to a reduction in the private demand for electricity generated from this source by 12.97%. Increased supplies of other base load electricity also lead the prices of these commodities to slightly decrease by 0.1% for gas-fired electricity, by 0.25% for wind electricity, by 0.11% for hydro electricity, and by 0.23% for other renewable electricity. Similar to the results in Scenario 1, the absolute values of the effects on the prices of electricity generated from these sources are relatively smaller than the effect on the price of electricity generated from coal-fired base load technology because of the substitution possibilities between these electricity sources. For example, the private sector increases its demand for electricity generated from other base load technologies, such as gas-fired (7.95%), wind (7.82%), hydro (7.97%), and other renewables (7.81%) in order to substitute for coal-fired base load electricity.

In Scenario 2, the impacts on the prices of electricity generated from gas-fired and oil-fired peak load technology are relatively small (i.e., 0.12% for gas-fired electricity and 0.16% for oil-fired

Table 4
Prices of electricity and private demand for electricity in Vietnam (percentage change).

Sectors	Electricity prices		Private demand	
	S1 (Petrol tax)	S2 (Coal tax)	S1 (Petrol tax)	S2 (Coal tax)
	(2)	(3)	(4)	(5)
Base load technology				
Coal electricity	0.93	21.49	11.22	−12.97
Gas electricity	11.28	−0.1	−3.25	7.95
Wind electricity	1.3	−0.25	12.21	7.82
Hydroelectricity	1.68	−0.11	9.74	7.97
Other renewable electricity	0.79	−0.23	11.93	7.81
Peak load technology				
Gas electricity	11.74	0.12	−3.69	−1.13
Oil electricity	20.82	0.16	−7.91	−1.11

Table 5
Free on board (f.o.b) price and real exports of coal, natural gas, and oil from Vietnam to China.

Commodity	S1 (petrol tax)			S2 (coal tax)		
	F.o.b price from Vietnam (% change)	Export (% change)	Export value (absolute change) ($ million)	f.o.b price from Vietnam (% change)	Export (% change)	Export value (absolute change) ($ million)
Coal	0.82	−4.45	−31.81	96.76	−97.91	−699.78
Natural gas	−0.04	1.00	7.65	−0.11	3.36	25.70
Crude Oil	−2.07	22.77	136.59	−0.25	2.58	15.48

electricity) because these two sectors do not use coal as inputs in their production processes. The impacts on the prices are determined by adjustments of the supply and demand curves and changes in the prices can be positive or negative depending on the effects on and the elasticities of these curves. Projections reported in Column (5) of Table 4 show that the private sector reduces its demand for electricity generated from gas-fired and oil-fired peak load technology by 1.13% and 1.11%, respectively.

Table 5 reports the percentage changes of the free on board (f.o.b) prices of coal, natural gas, and crude oil and percentage and absolute changes in real exports of these three commodities from Vietnam to China. We select China to illustrate the results because Vietnam mainly exports these three energy products to China. In Scenario 1, the impact on the supply of and demand for coal cause the export price of coal to increase by 0.82%, leading to a reduction in exports of coal from Vietnam by 4.45% (or $31.81 million). However, the export price of coal considerably increases by 96.76% in Scenario 2 due to increased tax on coal, leading to a substantial reduction in exports of coal to China by 97.91% (or $699.78 million). In both scenarios, the impacts on the export prices of natural gas and crude oil are relatively small. For example, the export price of natural gas declines by merely 0.04% and 0.11% in Scenarios 1 and 2, respectively. Hence, exports of natural gas to China increase by moderate 1% (or $7.65 million) in Scenario 1 and by 3.36% (or $25.7 million) in Scenario 2. Similarly, the export price of crude oil reduces by 2.07% in Scenario 1 and 0.25% in Scenario 2, leading to increased exports by 22.77% (or $136.59 million) and by 2.58% (or $15.48 million) in these two scenarios, respectively.

Table 6 reports the percentage and absolute changes in Vietnamese imports of main energy commodities from China. In Scenario 1, import of petroleum products is reduced by 17.3% (or $1105.6 million). It is a substantial change because any petroleum products consumed in Vietnam will be subject to a tax; hence, all sectors in Vietnam tend to reduce their demands for this commodity, including both domestic and international markets. By contrast, import of electricity from China increases in the face of rising prices of electricity in Vietnam with tax-induced increased production costs. Imports of coal-fired base load electricity increase by 2.58% (or $10.3 million), of wind base load electricity by 1.78% (or $0.33 million), of other renewable base load electricity by 1.43% (or $0.19 million), and of hydro peak load electricity by 5.52% (or $1.98 million).

In Scenario 2, the increased tax on coal results in sectors substituting other energy resources for coal, leading to an increase in the output level of the petroleum products manufacturing sector (Table 3). It consequently reduces the price of petroleum products in the domestic market; hence, imports of petroleum products from China slightly falls by 1.98% (or $126.5 million). Imports of electricity generated from different sources also increase due to higher prices of these commodities in Vietnam, for example, coal-fired base load electricity (14.25% or $56.6 million), wind base load electricity (7.61% or $1.4 million), other renewable base load electricity (7.6% or $1 million), and hydro peak load electricity (2.02% or $0.72 million).

4.2. Macroeconomic impact

Fig. 4 shows the impacts on the consumer price index and the terms of trade in Vietnam following the implementation of the increased taxes on fuels over different scenarios. The higher taxes indeed raise the costs of production, thereby affecting the supply prices of commodities. It consequently increases the consumer price index in Vietnam by 2.57% and 0.1% in Scenarios 1 and 2, respectively. In the application of GTAP-E-Power model, the world price is fixed because Vietnam is too small to influence the world market. Vietnam accounts for only a tiny fraction of the world trade; hence, any change in the Vietnamese domestic market is not able to change the world prices of commodities. As a result, an increased price index in Vietnam will lead to improve the terms of trade, worsening the competitiveness of Vietnam's exporters in its trade partners' markets. Depending on the effects of the increased taxes, the impact on the domestic price index and terms of trade will be different. For example, the terms of trade increases by a small margin of 0.31% when the tax on coal increases by 50% (Scenario 2) compared to the increase of the terms of trade of 1.09% when the tax on petroleum products increases by 33.33% (Scenario 1). This is the result of the shares of primary energy usages in Vietnam. The database shows that in the private commodity basket of primary energy consumed locally, petroleum products account for about 86%, while coal accounts for only 13%. In addition, all industrial sectors' consumption of petroleum products and coal respectively accounts for 47% and 35% out of the total primary energy consumption. Hence, the increased tax on petroleum products (Scenario 1) will cause higher impact on the Vietnamese economy compared to the increased tax on coal (Scenario 2).

Table 6
Changes in real exports from China to Vietnam.

	S1 (Petrol tax) (% change)	S2 (Coal tax) (% change)	S1 (Petrol tax) (Absolute change) ($ million)	S2 (Coal tax) (Absolute change) ($ million)
Petroleum products	−17.30%	−1.98%	−1105.6	−126.5
Coal electricity (BL)	2.58%	14.25%	10.3	56.6
Wind electricity (BL)	1.78%	7.61%	0.33	1.4
Other electricity (BL)	1.43%	7.60%	0.19	1.00
Hydro electricity (PL)	5.52%	2.02%	1.98	0.72

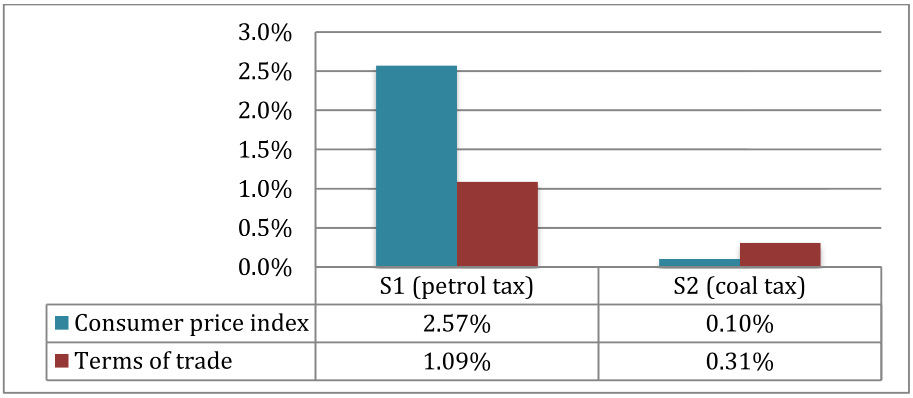


Fig. 4. Percentage change in the consumer price index and terms of trade in Vietnam.

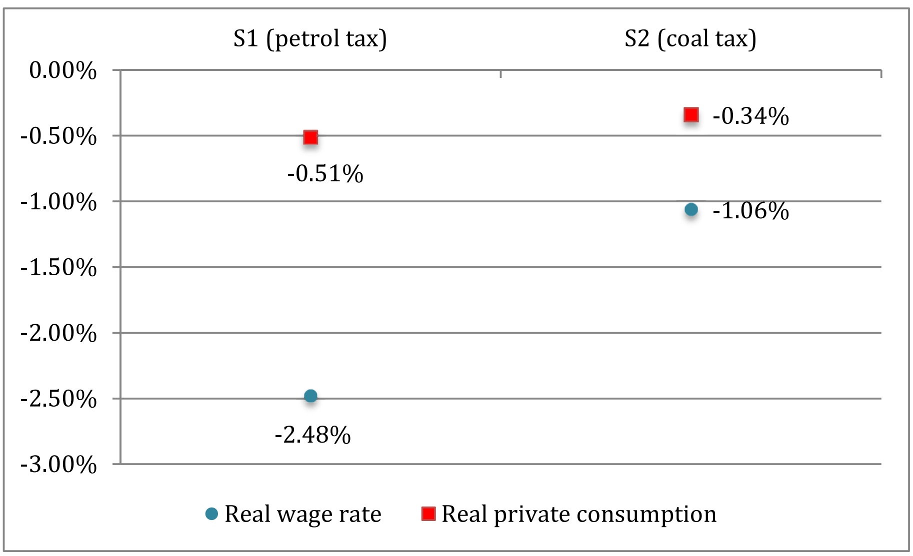


Fig. 5. Effects on the real wage rate and private consumption (percentage change).

Fig. 5 presents the impacts on the real wage rate and private consumption over the two scenarios. In our long run simulation, the employment is fixed at the baseline level. Since the increased taxes on petroleum products and coal add extra costs on producers, the real wage rate would decline to maintain the employment level relative to the baseline. The real wage adjusts according to the tax-induced cost increase on producers. In this instance, the increased tax on petroleum products generate higher costs than those from increasing the tax on coal; hence, the real wage rate declines by 2.48% in Scenario 1 compared to a reduction by 1.06% in Scenario 2. Such movements in the real wage rate reduce household's income. In addition, higher price levels diminish consumers' purchasing power. As a result, the real private consumption declines by 0.51% and 0.34% in Scenarios 1 and 2, respectively.

Fig. 6 shows additional results related to other key macroeconomic variables. Improvement of the terms of trade indicates that Vietnamese commodities become more expensive in the international market, subsequently causing the country's exports to decline. The impacts on real aggregate exports will depend on the effects on the terms of trade. For example, when the terms of trade improves by 1.09%, real exports decline by 5.47% (Scenario 1), whereas the improvement of the terms of trade by 0.31% contracts real exports by 1.64% (Scenario 2). The effects on the terms of trade also have implications for imports, that is, improvement of the terms of trade will encourage more imports because commodities from the international market become relatively cheaper. However, the increased taxes on fuels will worsen the Vietnamese economy and reduce the production levels. As a result, all sectors will reduce demand for inputs, including those from international and domestic markets. Hence, overall real imports will decline by 3.92% in Scenario 1 and 1.18% in Scenario 2.

The high price levels in the country tend to reduce the real public consumption. For example, the real public consumption declines by 0.41% in Scenario 1 and by 0.29% in Scenario 2 because the price increases are higher in Scenario 1. It is also noted that revenue collected from increased taxes contribute to the national income, which will be eventually allocated to the public and private sectors.[2] As a result, the impacts on the consumption levels of these sectors are moderate. In addition, the impacts on these two sectors are different because of the differences in their respective consumption baskets. The private sector consumes a large amount of

[2] The effects on private consumption are shown in Fig. 5.

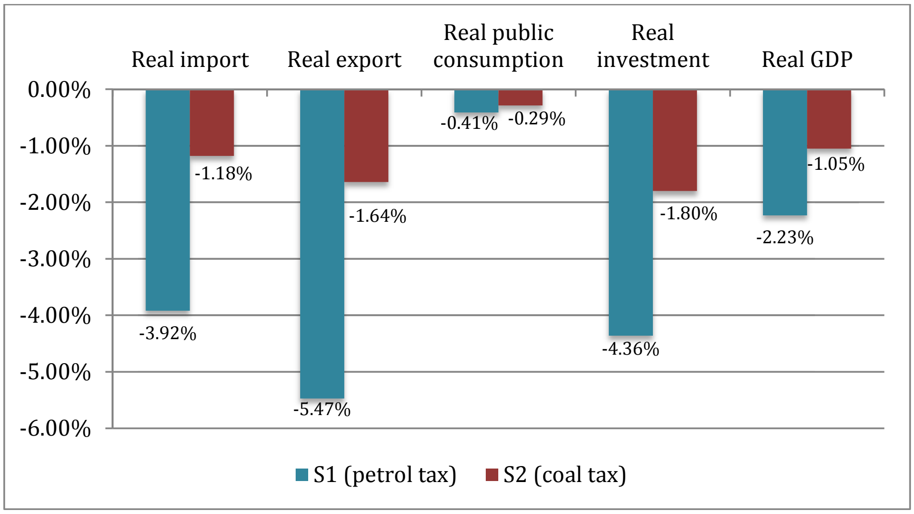


Fig. 6. Effects on real GDP and other variables (percentage changes).

energy commodities for which the prices have increased due to increased costs on their production processes, while the public sector primarily demands services. As a result, the private sector bears a higher reduction in consumption relative to the reduction in the consumption of the public sector. Fig. 6 also shows that costs on the production processes increase the costs of investment, leading to the reduction in the real investment by 4.36% in Scenario 1 and 1.8% in Scenario 2. The impacts on trade, consumption, and investment contribute to the reductions in real GDP by 2.23% in Scenario 1 and by 1.05% in Scenario 2. It is evident that the increased tax on petroleum products yields a higher cost on the Vietnamese economy compared to the tax on coal because the consumption level of petroleum products are relatively higher than coal consumption in Vietnam.

Fig. 7 shows that the increased tax on coal yields higher reductions in both CO_2 and non-CO_2 emissions levels compared to the reduction rates from increased tax on petroleum products. For example, the CO_2 and non-CO_2 emission levels are reduced by 11.18% and 9.44%, respectively, when the tax on coal increases by 50%, while these emissions decline by 10.4% and 5.31% when the tax on petroleum products is increased by 33.33%. As a result, a decline in total emissions of 10.23% in Scenario 2 shows that the increased tax on coal offers Vietnam a more efficient emission reduction than the increased tax on petroleum products, which only helps the country to reduce its emission level by 7.62%. This variation is due to the fact that coal has a relatively higher emission-intensity than petroleum products.

5. Conclusion and policy implications

This study employed the GTAP-E-Power model with an extension to include non-CO_2 emissions to examine the impacts of increased energy taxes on the Vietnamese economy and different electricity generation and other energy sectors. Numerous studies have only used CO_2 emissions in the database, which underestimates the impacts on emission levels. Such an incorporation

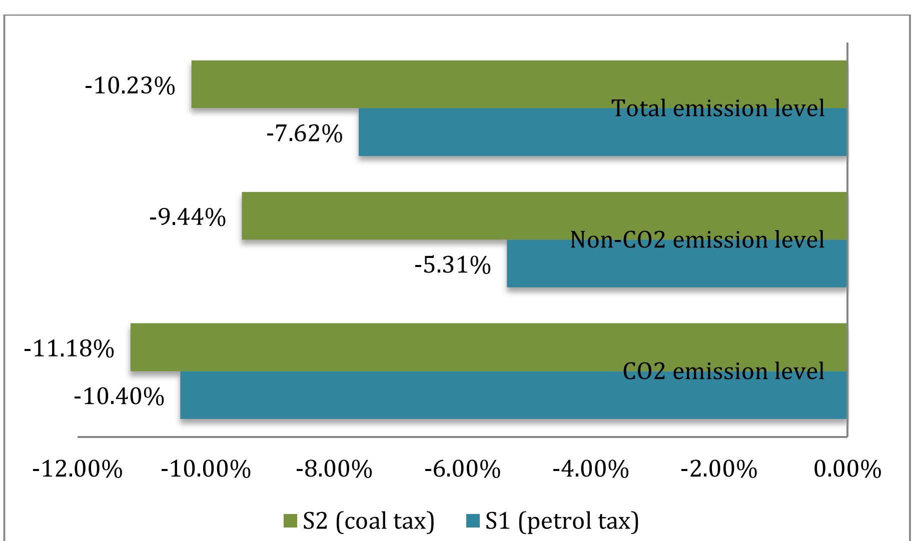


Fig. 7. Percentage changes in the emission levels.

of non-CO_2 emissions in the GTAP-E-Power model is a novel feature in the literature that also allows estimating more accurately the economy-wide impacts of climate change policies, such as carbon taxes or emissions trading schemes. This is because the costs on sectors will be significantly different when additional emission levels (non-CO_2) are incorporated.

We simulated two potential energy tax scenarios in this study for Vietnam. That is, a tax on petroleum products was increased by 33.33% in Scenario 1 and a tax on coal was increased by 50% in Scenario 2. Since the GTAP-E-Power model has a linear modeling approach, the results of implementing both tax increases can be deduced by aggregating the corresponding results in Scenarios 1 and 2. Results show several important outcomes. First, the increased tax on petroleum products affects the Vietnamese economy more severely than in the case of increased tax on coal. For example, real GDP reduces by 2.23% in Scenario 1 and by 1.05% in Scenario 2. Real imports, exports, and investment are also more adversely affected in Scenario 1 than in Scenario 2. This is because petroleum products are the main energy source for both industrial and private sectors in Vietnam compared to consumption levels of coal. Second, the increased taxes on coal and petroleum products reduce output levels of those extraction and manufacturing sectors, leading to higher supply prices. Such price escalations affect the Vietnamese economy and related electricity generation sectors (coal-fired and gas-fired electricity generation) considerably. Note that coal and petroleum products are the main inputs to these sectors.

Third, the low emission-intensive electricity generation sectors are noticeably better off with increased output levels allowing substitution for shortfalls in electricity outputs generated from the other sources. For example, output levels of gas, wind, hydro, and other renewable electricity would increase by around 8% each if the tax on coal increased by 50%. If the tax increases were concurrent, the renewable electricity generation sectors would experience substantial improvements in their outputs. In this environment, the private sector also considerably increases its demand for electricity generated from renewable sources. For instance, the private demand for electricity generated from wind, hydro power, and other renewable resources would expand by 12.21%, 9.74%, and 11.93%, respectively when the tax on petroleum products were raised by 33.33%. In addition, the private demand for these electricity commodities would rise by 20.03%, 17.71%, and 19.74% when these two taxes were increased simultaneously. Fourth, the increased tax on coal yields smaller unfavorable impact on the Vietnamese economy but is able to help the country to reduce the emissions level by a relatively higher margin compared to the increased tax on petroleum products. If these taxes were increased simultaneously, Vietnam is projected to reduce its emission level by 17.8%. Such a significant reduction in the emissions is helpful for Vietnam, as the country further committed to reduce its emissions at the Paris Climate Change Conference.

These findings have several important policy implications. Depending on the tax target, related energy sectors would experience noticeable reductions in their production levels. Furthermore, some adverse effects are transmitted to a higher number of industries if these two taxes are increased together. As a result, input used by these sectors will be affected. In particular, demands for labor would reduce substantially in some industries. Although the aggregate employment level is unchanged in the long run simulations, labor can move between industries but this process takes time. The results show that the real wage rate also declines to maintain the fixed aggregate employment level. The reduced income via low wages subsequently affects households. The outcomes may be worsened if people working in these sectors are the main breadwinners for their households. Hence, there should be supporting policies to alleviate loss of employment in these industries and to help labor to gain employment in other industries. In addition, the government may need to consider appropriate policies to support coal mining, petroleum products manufacturing, coal-fired electricity generation, and gas-fired electricity generation sectors because they are significant sectors in the Vietnamese economy. The growth of the renewable electricity generation sectors will be significant, which would need additional supporting policies to increase investment and to sustain growth in them. As a result, new employment opportunities can be created within them to absorb unemployed labor due to these taxes in the economy.

Appendix A

Table A1
Region and industry aggregation.

Aggregated regions	Aggregated industrial sectors
1. Vietnam	1. Rice
2. Japan	2. Wheat
3. United States	3. Grains
4. European Union 28	4. Vegetables, fruits, nuts
5. China	5. Oil seeds
6. Rest of the World	6. Sugar cane and sugar
	7. Plant-based fibbers
	8. Other crops
	9. Cattle, sheep, goats
	10. Other animal products
	11. Raw milk
	12. Wool silk-warm cocoons
	13. Forestry
	14. Fishing
	15. Coal extraction
	16. Crude oil extraction
	17. Natural gas extraction
	18. Petroleum products manufacturing
	19. Electricity transmission
	20. Nuclear base load electricity
	21. Coal base load electricity
	22. Gas base load electricity
	23. Wind base load electricity
	24. Hydro base load electricity
	25. Oil base load electricity
	26. Other renewable base load electricity
	27. Gas peak load electricity
	28. Hydro peak load electricity
	29. Oil peak load electricity
	30. Solar peak load electricity
	31. Energy intensive industries
	32. Other industries
	33. Services

Table A2
Key indexes in the GTAP-Power database in 2011.

	GDP ($ million)	Income ($ million)	Export (f.o.b price, $ million)	Import (c.i.f price, $ million)	CO2 emissions (Mt)	Non-CO2 emissions (Mt)
Vietnam	135540.0	112940.8	97108.5	121474.0	127.3	148.6
Japan	5905634.5	4878827.5	943337.1	956997.8	1030.1	90.4
USA	15533786.0	13611061.0	1880767.1	2676775.5	5108.0	967.4
EU 28	18815944.0	16323820.0	7492573.0	7534090.5	3796.7	1147.4
China	7570390.5	6497902.5	2144014.0	1833688.5	7324.7	2687.3
Rest of the world	23515851.0	20613608.6	7596134.3	7030908.5	11431.6	7630.5

Table A3
Output values by commodity in each country at agent prices ($ million) in the GTAP-Power database in 2011.

	Vietnam	Japan	USA	EU 28	China	Rest of the world
1. Rice	19950.5	49981.4	8385.3	6339.7	115986.0	344722.8
2. Wheat	1.3	549.1	20612.4	40827.5	35911.3	128020.8
3. Grains	234.5	177.4	73345.5	38195.5	61451.3	157204.3
4. Vegetables, fruits, nuts	6541.9	31757.2	70437.1	89793.6	282708.5	589989.2
5. Oil seeds	100.7	492.2	37483.5	22865.7	32203.5	177039.9
6. Sugar cane and sugar	2137.8	5473.8	17844.7	29760.3	23067.7	221477.5
7. Plant-based fibbers	84.4	73.1	10374.8	1423.5	17430.2	63155.8
8. Other crops	3826.1	21040.5	18819.1	87336.9	5774.1	252313.1
9. Cattle, sheep, goats	1275.2	6601.4	50152.7	49894.3	64610.6	175564.6
10. Other animal products	4845.8	15592.3	55418.1	92218.8	276741.5	222840.0
11. Raw milk	1.4	8450.3	38945.3	77217.1	19372.6	202888.1
12. Wool silk-warm cocoons	30.3	825.2	56.4	685.7	12543.7	31881.4
13. Forestry	2617.1	6169.5	22270.2	56599.7	61384.5	135442.1
14. Fishing	7385.4	18836.8	8088.0	39105.7	110625.4	145576.9
15. Coal extraction	3629.3	99.6	71534.2	39047.8	149072.3	174799.4
16. Crude oil extraction	8627.8	495.8	212268.6	133142.0	121081.5	2017293.2
17. Natural gas extraction	1878.2	2337.5	91990.3	86982.7	7007.3	484580.6
18. Petroleum products manufacturing	6601.6	216848.2	710605.9	804503.4	543465.9	1757532.8
19. Electricity transmission	3232.9	43536.5	85471.8	123192.4	61924.7	192819.2
20. Nuclear base load electricity	0.0	12825.1	57314.1	98068.4	4368.2	35295.3
21. Coal base load electricity	2194.1	28963.1	139590.5	99549.5	160492.1	164499.8
22. Gas base load electricity	2578.4	45115.0	24200.6	50052.7	523.5	159496.2
23. Wind base load electricity	17.2	895.1	10444.7	36510.5	4257.6	6903.6
24. Hydro base load electricity	4965.7	21284.5	33935.0	39357.1	1365.0	91553.2
25. Oil base load electricity	0.0	0.0	0.0	3146.3	0.0	66479.2
26. Other renewable base load electricity	13.2	8809.6	7975.3	36676.0	5521.6	17218.6
27. Gas peak load electricity	1501.7	2909.3	40362.7	49420.9	12711.5	97768.0
28. Hydro peak load electricity	0.0	0.0	0.0	11564.1	40508.7	18692.1
29. Oil peak load electricity	891.5	40803.3	6415.7	18976.1	3033.4	94202.0
30. Solar peak load electricity	0.0	2175.3	1298.1	18834.2	173.2	920.1
31. Energy intensive industries	30562.2	1010276	1676818.3	3021389.3	3930792.8	4337513.5
32. Other industries	104228.9	2325816	5108076	8334903	7053880	8730738
33. Services	86410.3	7422265	18919870	22133976	7479136.0	22571733

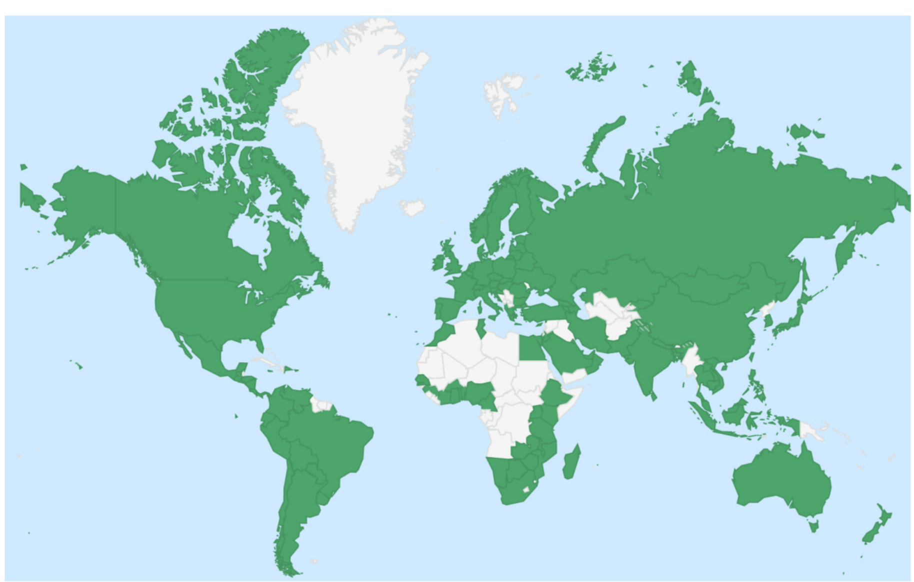


Fig. A1. Regions in the GTAP-Power database in 2011.
Note: Green includes countries that have data.
Source: https://www.gtap.agecon.purdue.edu/databases/regions.aspx?version=9.211

Appendix B

In this section, we will provide the robustness of the results based on the systematic sensitivity analysis subject to changing key parameters. In particular, this study used the GTAP-E-Power model, which has new production and consumption structures for the electricity generation sectors and commodities compared to those in the original GTAP-E model. That is, electricity generation and demand are divided into base load and peak load technologies with substitution possibilities among each group. In particular, Peters (2016a) assumed that the CES for base load electricity generated from different sources has a value of 1.386 and it is 0.472 for peak load electricity generated from different sources. In this study we have examined how the results in Scenario 1 will change when these two parameters are altered simultaneously for all sectors in Vietnam. In this instance, it is assumed that the parameters will be changed by ± 50% from the original values of 1.386 and 0.472.

Table B1
Results in Scenario 1 subject to changes in parameters (percentage change).

Variable	Original results (1)	Lower bound (2)	Upper bound (3)	Difference between lower and upper bound results (4)
Macroeconomic impact				
Real GDP	−2.23	−2.27	−2.19	0.09
Real private consumption	−0.51	−0.51	−0.51	0.00
Real public consumption	−0.41	−0.41	−0.41	0.00
Real investment	−4.36	−4.54	−4.18	0.36
Real export	−5.47	−5.47	−5.47	0.00
Real import	−3.92	−3.92	−3.92	0.00
Sectoral impact				
Output of gas BL electricity	−11.98	−20.55	−3.39	17.16
Output of gas PL electricity	−1.92	−2.23	−1.61	0.63
Output of oil PL electricity	−5.7	−8.78	−2.62	6.17
Private demand for coal BL electricity	11.22	−7.96	14.48	6.53
Private demand for gas BL electricity	−3.25	−12.66	6.20	18.86
Private demand for wind BL electricity	12.21	8.01	16.41	8.40
Private demand for hydro BL electricity	9.74	7.86	11.62	3.75
Private demand for other renewable BL electricity	11.93	8.00	15.86	7.87
Private demand for gas PL electricity	7.91	7.60	8.22	0.63
Private demand for oil PL electricity	3.69	0.20	7.18	6.97

Note: BL and PL refer to base load and peak load, respectively. The results in column (1) indicate the results analyzed in Scenario 1 when using the parameter values of 1.386 for substitution possibility between base load electricity sources and 0.472 for substitution possibility between peak load electricity sources. Results in columns (2) and (3) represent the lower bound and upper bound results, respectively, when these parameters change together for all sectors in Vietnam.

The results in Table B1 show that changing these parameters by ± 50% only slightly changes the macroeconomic impacts on the Vietnamese economy. However, the sectoral results may change substantially if these parameters are altered simultaneously by ± 50% for all industries in Vietnam. For example, the output level of and private demand for electricity generated from gas-fired base load technology could fluctuate at high rates. Private demands for electricity from other sources could also change considerably due to changing these parameters. Such findings indicate that the macroeconomic impacts of the increased taxes would not be changed greatly due to relaxing the parameters but the sectoral impacts are highly sensitive.

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